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⑲ 日本国特許庁 (JP)　　⑪ 特許出願公開

⑫ 公開特許公報 (A)　　昭57—79909

⑤1Int. Cl.³　識別記号　庁内整理番号　⑬公開 昭和57年(1982)5月19日
G 02 B 15/10　7448—2H

発明の数 1
審査請求 有

(全 7 頁)

⑤4天体望遠鏡の光学系

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⑦1特願 昭55—155182
⑦2出願 昭55(1980)11月6日
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明　細　書

1．発明の名称　天体望遠鏡の光学系

2．特許請求の範囲

天体望遠鏡対物レンズ(の後群レンズ)を装脱自在にするために、複数のレンズから構成される正の焦点距離(f_1)、Fナンバー(F_1)を有する前群レンズはこれ自体が収差補正され、天体望遠鏡の対物レンズとして使用することができ、この前群レンズに対して正のレンズと負のレンズを空気間隔をとつて配置し、正の焦点距離(f_2)を有する後群レンズを大きな空気間隔をとつて配置して得られる(光学系)~~対物レンズ~~の焦点距離(f)、後群レンズの前面から前群レンズの焦点位置までの距離を(ℓ)とすると、

$$1.0 < \frac{f_2}{f} < 3.0 \quad \cdots\cdots\cdots (1)$$

$$2.0 < \frac{f_2}{f_2} < 6.0 \quad \cdots\cdots\cdots (2)$$

$$8 \leqq F_1 \leqq 15 \quad \cdots\cdots\cdots (3)$$

$$0.05\, f_1 \leqq \ell \leqq 0.2\, f_1 \quad \cdots\cdots (4)$$

の諸条件を満足した天体望遠鏡の光学系。

3．発明の詳細な説明

本発明は天体望遠鏡対物レンズの焦点位置の手前、適り位置に正の焦点距離を有する後群レンズを配置し、しかも、この後群レンズは補正レンズとしてアダプター形式に使用可能にし、対物レンズのFナンバーを明るくし、更に像面湾曲、コマ収差を改善せしめる目的のために創作された天体望遠鏡の光学系に係るものであり、その目的とするところは、1台の天体望遠鏡で二様の使い方ができる光学系としたものである。

天体望遠鏡の対物レンズは負の像面湾曲とコマ収差が残存しているため狭画角に使用されている。接眼レンズも対物レンズと同様に負の像面湾曲を有するため眼視観測、又、写真撮影においても対物レンズの像面を平坦化されることが望まれる。

本発明は上記の要望を満足するために構成されたもので、複数枚のレンズから構成される正の焦点距離(f_1)、Fナンバー(F_1)を有する前群レンズはこれ自体が収差補正されており、天体望遠鏡の

対物レンズとして使用することができ、この前群レンズ(L)に対して正のレンズと負のレンズを空気間隔をとつて配置し、正の焦点距離(f_2)を有する後群レンズ(L')とは大きな空気間隔をとつて配置して得られる~~対物レンズ~~光学系の焦点距離(f)、後群レンズの前面から前群レンズの焦点位置までの距離を(ℓ)とすると、

$$1.0 < \frac{f_1}{f} < 3.0 \quad \cdots\cdots\cdots\cdots (1)$$

$$2.0 < \frac{f_1}{f_2} < 6.0 \quad \cdots\cdots\cdots\cdots (2)$$

$$8 \leqq F_1 \leqq 15 \quad \cdots\cdots\cdots\cdots (3)$$

$$0.05 f_1 \leqq \ell \leqq 0.2 f_1 \quad \cdots\cdots\cdots (4)$$

の諸条件を満足した天体望遠鏡の光学系としたものである。(第1図参照)

上記説明中、条件(1)の$\frac{f_1}{f}$は後群レンズの前群レンズ焦点距離に対しての縮小倍率の逆数を現わし、この範囲の最大値を越えた場合は、後群レンズの各面の曲率半径が小さくなるため、コマ収差、非点収差の補正が困難となる。又、最小値を越した場合は、1台の天体望遠鏡を二様に用いると云う点から考えると利点がなくなる。

条件(2)により前群及び後群レンズの空気間隔を大きく保つことにより後群レンズを補助レンズとして独立させ、アダプター形式にする方式も可能になり、アダプターレンズとして前群レンズのFナンバーが8より大きな既製の天体望遠鏡に装着しても像面彎曲の収差を良好に補正し、かつ、使用される対物レンズのF-ナンバーを明るくすることができる。

条件(4)は後群レンズの配置を規正し、前群レンズが有する上記条件(3)の範囲内のFナンバーと関係し、条件(4)の範囲内の数値を選定することによつて収差を良好に保つた状態で、適つた後側焦点距離を得る。

上記(1)(2)(3)の諸条件を満足した前群レンズは、これ自体収差補正がされており、天体望遠鏡対物レンズとして使用することができるものである。

上記の如く(1)(2)(3)の諸条件を満足する任意の焦点距離の前群レンズにアダプター形式の後群レンズを装着すると、Fナンバーは$F_1 \times \frac{f}{f_1}$と明るくすることができ、コマ収差、像面彎曲収差を良好に補正できる天体望遠鏡対物レンズとなしうるものである。換言すれば、1台の天体望遠鏡にアダプターとして後群レンズ(補助レンズ)を使用することにより、Fナンバーの異なる2台の天体望遠鏡として使用することが可能となる光学系である。

次に、本発明の実施例を示す。

実施例(一)

(L_1)(L_2)の前群レンズと、(L_3)(L_4)の後群レンズよりなり、(第2図参照)

焦点距離　$f = 824.323$ mm

後側焦点距離　$Bf = 52.928$ mm

Fナンバー　$F = 10.3$

前群レンズの焦点距離　$f_1 = 1,200.00$ mm

・後側焦点距離　$Bf_1 = 1,191.790$ mm

・Fナンバー　$F_1 = 15$

後群レンズの焦点距離　$f_2 = 241.372$ mm

・後側焦点距離　$Bf_2 = 218.735$ mm

			nd	νd
前群レンズ	$R_1 = +664.0$	$d_1 = 10$	1.43387	95.2
	$R_2 = -357.401$	$d_2 = 0.175$		
L_1	$R_3 = -361.182$	$d_3 = 7$	1.5213	52.6
L_2	$R_4 = -1,269.71$	$d_4 = 1,092.8324$		
後群レンズ	$R_5 = +121.2$	$d_5 = 8$	1.63854	55.4
L_3	$R_6 = -169.7$	$d_6 = 7.866$		
L_4	$R_7 = -140.0$	$d_7 = 3$	1.74	28.3
	$R_8 = \infty$			

(但し　$R_1 \sim R_8$ はレンズの各面の曲率半径(mm)
$d_1 \sim d_7$ はレンズ肉厚及び空気間隔(mm)
nd は d線に対するレンズの屈折率
νd はレンズのアッベ数)

尚、上記実施例の収差は第3図に示す。

上記実施例は前群レンズと補助レンズの後群レンズを組合せたものであるが、次に前群レンズのみで後群レンズのアダプターを外した場合の収差の比較示す。

前群レンズのみでは焦点距離が上記実施例より長いため、同一焦点距離として比較すると収差の比較上わかり易いので、前群レンズのデータに f/f_1 の比例をかけて得られたレンズ系のデータを下記に示す。尚、レンズ系の外観図を第4図に、これが収差を第5図に示す。

焦点距離　$f' = 824.323$ mm

後側焦点距離　$Bf' = 818.688$ mm

Fナンバー　$F' = 10.3$

			nd	νd
L_1	$R_1 = +456.129$			
		$d_1 = 6.8694$	1.43387	95.2
	$R_2 = -245.513$			
		$d_2 = 0.1202$		
L_2	$R_3 = -248.111$			
		$d_3 = 4.806$	1.5213	52.6
	$R_4 = -892.217$			

実施例(二)

$(L_1)(L_2)$ の前群レンズと、$(L_3)(L_4)$ の後群レンズよりなり、(第6図参照)

焦点距離　$f = 439.642$ mm

後側焦点距離　$Bf = 52.928$ mm

Fナンバー　$F = 5.5$

前群レンズの焦点距離　$f_1 = 640.00$ mm

〃　後側焦点距離　$Bf_1 = 629.197$ mm

〃　Fナンバー　$F_1 = 8.0$

後群レンズ……は実施例(一)の後群レンズと同じ

			nd	νd
前群レンズ L_1	$R_1 = +354.133$			
		$d_1 = 14.5573$	1.43387	95.2
	$R_2 = -188.546$			
		$d_2 = 0.1747$		
L_2	$R_3 = -190.773$			
		$d_3 = 7.2786$	1.5213	52.6
	$R_4 = -672.8086$			
		$d_4 = 530.23863$		
後群レンズ L_3	$R_5 = +121.2$			
		$d_5 = 5.0$	1.63854	55.4
	$R_6 = -169.7$			
		$d_6 = 7.866$		
L_4	$R_7 = -140.0$			
		$d_7 = 3.0$	1.74	28.3
	$R_8 = \infty$			

尚、上記実施例の収差は第7図に示す。

上記実施例は前群レンズと補助レンズの後群レンズを組合せたものであるが、次に前群レンズのみで後群レンズのアダプターを外した場合の収差の比較を示す。

前群レンズのみでは焦点距離が上記実施例より長いため、同一焦点距離として比較すると収差の比較上わかり易いので、前群レンズのデータに f/f_1 の比例をかけて得られたレンズ系のデータを下記に示す。尚、レンズ系の外観図を第8図に、これが収差図を第9図に示す。

焦点距離　$f' = 439.642$ mm

後側焦点距離　$Bf' = 432.221$ mm

Fナンバー　$F' = 5.5$

			nd	νd
L_1	$R_1 = +243.269$			
		$d_1 = 10.0$	1.43387	95.2
	$R_2 = -129.520$			
		$d_2 = 0.12$		
L_2	$R_3 = -131.050$			
		$d_3 = 5.0$	1.5213	52.6
	$R_4 = -462.180$			

4. 図面の簡単な説明

第1図は本発明光学系の説明図、第2図は第一実施例の光学系を示す側面図、第3図は同上収差を示し、(Ⅰ)は球面収差、(Ⅱ)は非点収差、(Ⅲ)は歪曲収差を示す。第4図は第一実施例の焦点距離と同一の焦点距離にした前群レンズのみの側面図、第5図は同上収差を示し、(Ⅰ)は球面収差、(Ⅱ)は非点収差、(Ⅲ)は歪曲収差を示す。第6図は第二実施例の光学系の側面図、第7図は同上収差を示し、(Ⅰ)は球面収差、(Ⅱ)は非点収差、(Ⅲ)は歪曲収差を示す。第8図は第二実施例の焦点距離と同一焦点距離にした前群レンズのみの側面図、第9図は同上収差を示し、(Ⅰ)は球面収差、(Ⅱ)は非点収差、(Ⅲ)は歪曲収差を示す。

尚、図中符号 $(L_1)(L_2)$ …前群レンズ

$(L_3)(L_4)$ …後群レンズ

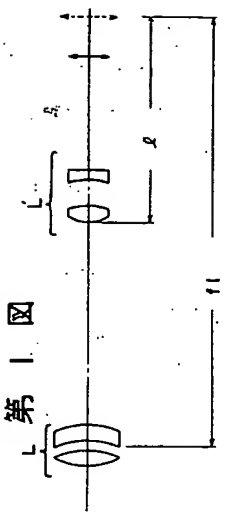
特許出願人

株式会社五藤光学研究所

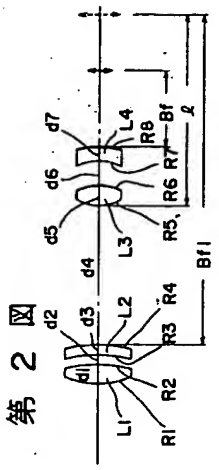
代理人

神保　勉　(外1名)

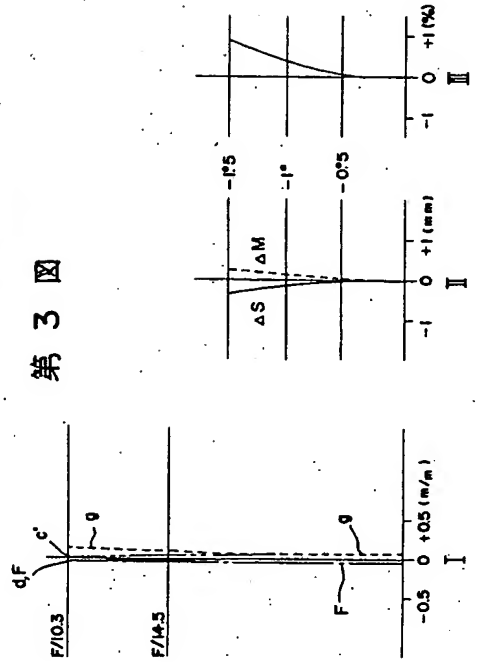
第1図



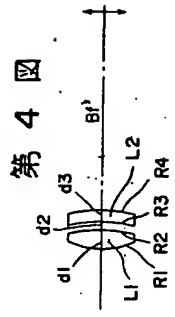
第2図



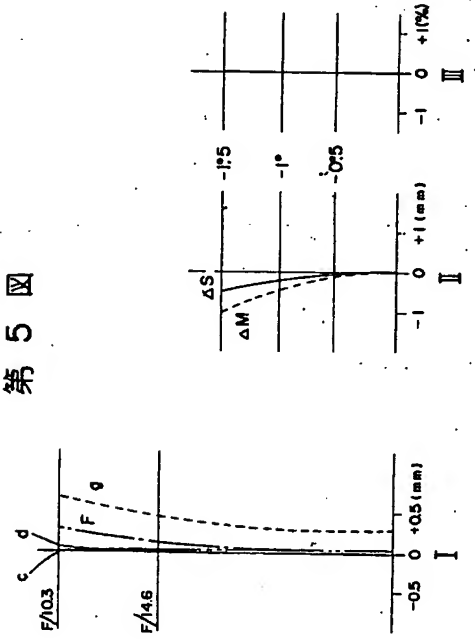
第3図



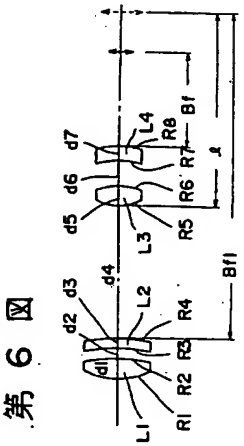
第4図



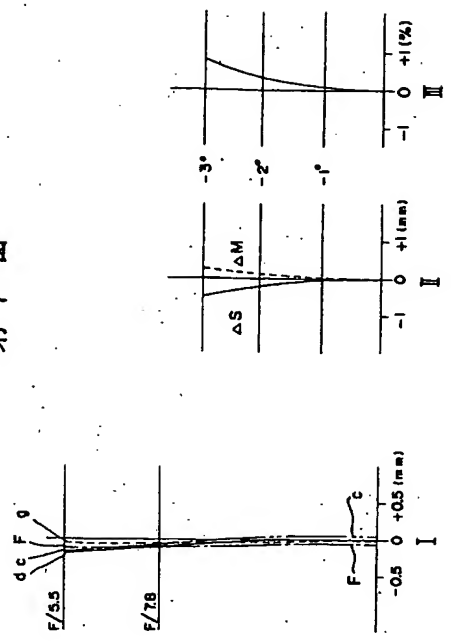
第5図



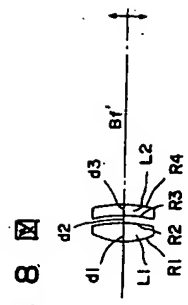
第6図



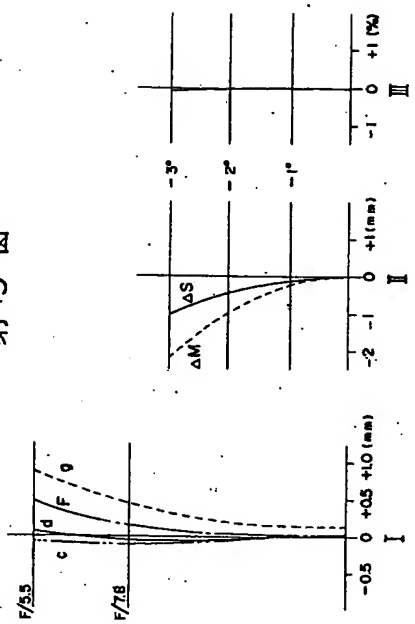
第7図



第8図



第9図



手続補正書　（方式）

昭和５６年４月１０日

特許庁長官　島　田　春　樹　殿

1．事件の表示　昭和５５年特許願第１５５１８２号

2．発明の名称　天体望遠鏡の光学系

3．補正をする者

事件との関係　特許出願人

〒　183

住　所　東京都府中市矢崎町４丁目１６番地

名　称　株式会社　五藤光学研究所

4．代　理　人

〒　154

住　所　東京都世田谷区若林２丁目３２番２３号

氏　名　（5569）神　保　勉　（外１名）

5．補正命令の日付

昭和５６年３月５日

6．補正の対象　委任状、明細書の図面の簡単な説明の項及び添付図面

特許庁 56.4.10

7．補正の内容

(1) 委任状「別紙の通り」

(2) 明細書中、図面の簡単な説明を次の通り補正する。

「４．図面の簡単な説明

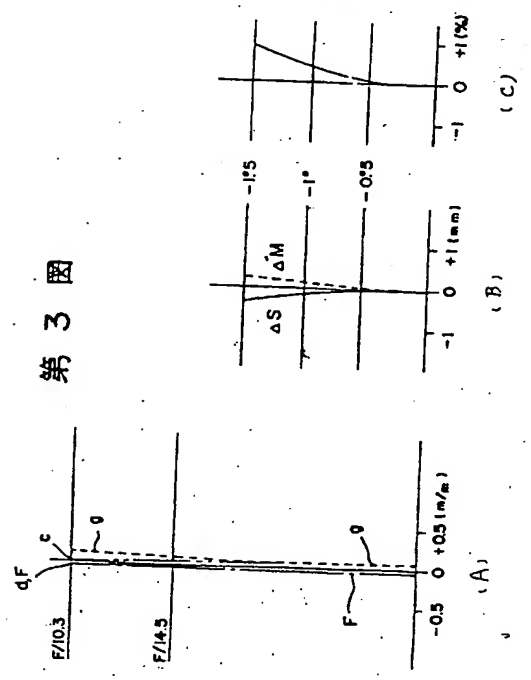
第１図は本発明光学系の説明図、第２図は第一実施例の光学系を示す側面図、第３図は同上収差を示し、(A)は球面収差、(B)は非点収差、(C)は歪曲収差を示す。第４図は第一実施例の焦点距離と同一の焦点距離にした前群レンズのみの側面図、第５図は同上収差を示し、(A)は球面収差、(B)は非点収差、(C)は歪曲収差を示す。第６図は第二実施例の光学系の側面図、第７図は同上収差を示し、(A)は球面収差、(B)は非点収差、(C)は歪曲収差を示す。第８図は第二実施例の焦点距離と同一焦点距離にした前群レンズのみの側面図、第９図は同上収差を示し、(A)は球面収差、(B)は非点収差、(C)は歪曲収差を示す。

尚、図中符号　$(L_1)(L_2)$…前群レンズ

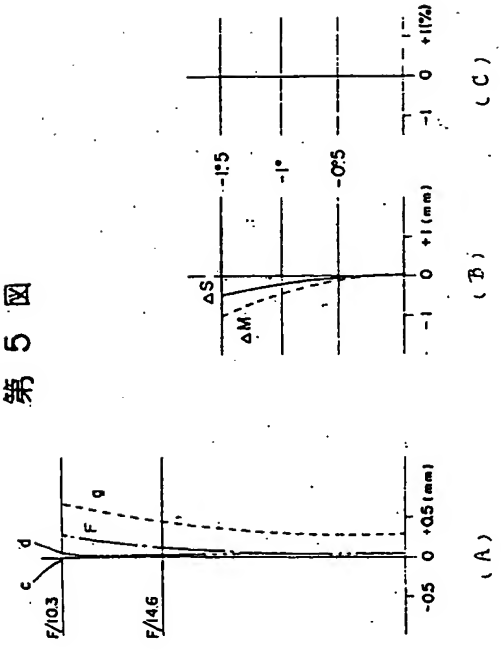
$(L_3)(L_4)$…後群レンズ

(8) 添付図面中「第3、5、7、9図」を別紙の通り補正する。

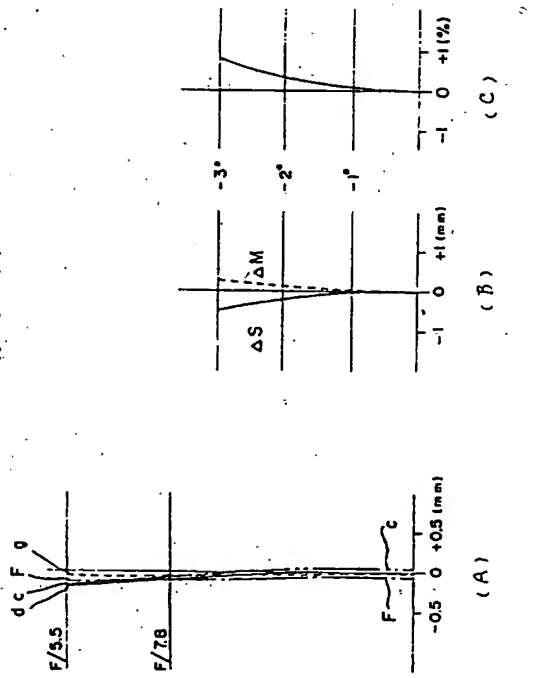
第3図



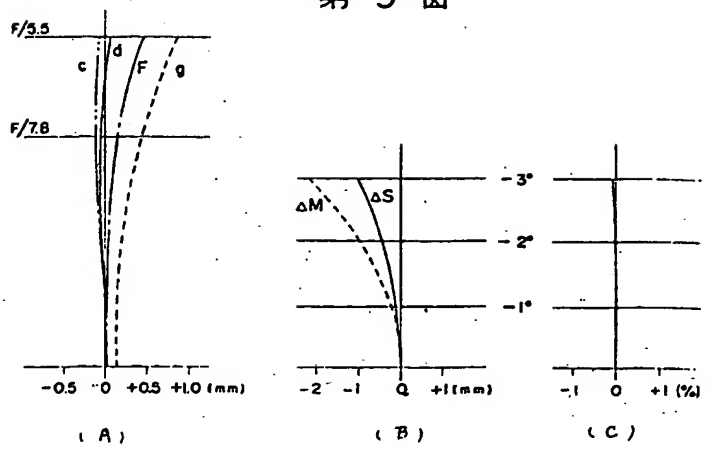
第5図



第7図



第 9 図



(A)　　(B)　　(C)

ASTRONOMICAL TELESCOPE OPTICAL SYSTEM

Japanese Unexamined Patent No. Sho-57-79909

Laid-open on: May 19, 1982

Application No. Sho-55-155182

Filed on: November 6, 1980

Inventor: Shoichi ARAYA

Applicant: GOTO OPTICAL MFG. CO.

SPECIFICATION

1. TITLE OF THE INVENTION

ASTRONOMICAL TELESCOPE OPTICAL SYSTEM

2. WHAT IS CLAIMED IS;

An astronomical telescope optical system, wherein, in order to make a rear lens group of an astronomical telescope objective lens attachable and detachable, a front lens group that is composed of a plurality of lenses and has a positive focal length (f_1) and f-number (F_1) is corrected for aberrations itself and can be used as an objective lens of the astronomical telescope, and a positive lens and a negative lens are arranged in this front lens group while leaving an air space, and a rear lens group having a positive focal length (f_2) is disposed while leaving a large air space, and when the focal length of an optical

system thus obtained is defined as (f) and the distance from the front surface of the rear lens group to the focal point of the front lens group is defined as (ℓ), the following conditions are satisfied:

$$1.0 < f_1/f < 3.0 \cdots\cdots\cdots (1)$$

$$2.0 < f_1/f_2 < 6.0 \cdots\cdots\cdots (2)$$

$$8 \leq F_1 \leq 15 \cdots\cdots\cdots\cdots (3)$$

$$0.05\ f_1 \leq \ell \leq 0.2\ f_1 \cdots\cdots (4)$$

3. DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to an astronomical telescope optical system invented for the purpose that a rear lens group having a positive focal length is disposed at a proper position in front of the focal point of an astronomical telescope objective lens, and this rear lens group is made available as a correcting lens of an adapter type, the f-number of the objective lens is improved, and furthermore, curvature of field and coma aberration are improved, and the object of the invention is to provide an optical system which can be used in two ways in one astronomical telescope.

An astronomical telescope objective lens has been used for a narrow angle of field since negative curvature of field and coma aberration remains therein. Since an eyepiece also has negative curvature of field as in the case with the objective

lens, it has been demanded to make the image surface of the objective lens plane in visual observation and photographing.

The present invention has been made in order to satisfy the abovementioned demands, a front lens group that is composed of a plurality of lenses and has a positive focal length (f_1) and f-number (F_1) is corrected for aberrations itself and can be used as an astronomical telescope objective lens, and a positive lens and a negative lens are disposed in this front lens group (L) while leaving an air space so as to have a large air space from a rear lens group (L') having a positive focal length (f_2), and when the focal length of an optical system thus obtained is defined as (f), and the distance from the front surface of the rear lens group to the focal point of the front lens group is defined as (ℓ), the following conditions are satisfied (see Fig. 1).

$$1.0 < f_1/f < 3.0 \cdots\cdots\cdots (1)$$

$$2.0 < f_1/f_2 < 6.0 \cdots\cdots\cdots (2)$$

$$8 \leq F_1 \leq 15 \cdots\cdots\cdots\cdots (3)$$

$$0.05\ f_1 \leq \ell \leq 0.2\ f_1 \cdots\cdots (4)$$

In the above description, f_1/f of the condition (1) shows the reciprocal of the condensing ratio of the rear lens group to the focal length of the front lens group, and when the maximum value of this range is exceeded, since the radius of curvature

of each surface of the rear lens group becomes smaller, it becomes difficult to correct coma aberration and astigmatism. On the other hand, the case where the minimum value is exceeded is not advantageous in terms of two-way use of one astronomical telescope.

According to the condition (2), by maintaining a large air space between the front lens group and the rear lens group, the rear lens group can be made independent as an auxiliary lens of an adapter type, and even when such a rear lens group is attached to a ready-made astronomical telescope the front lens group of which has an f-number larger than 8, curvature of field is excellently corrected, and the f-number of an objective lens in use can be reduced.

The condition (4) regulates the arrangement of the rear lens group, and concerns the f-number within the range of the condition (3), which the front lens group has, and in a condition where aberrations are properly controlled by selecting a value within the range of the condition (4), a proper back focal length is obtained.

A front lens group satisfying the abovementioned conditions (1), (2), and (3) itself is aberration-corrected, and can be used as an astronomical telescope objective lens.

When an adapter type rear lens group is attached to the front

lens group having an optional focal length satisfying the abovementioned conditions (1), (2), and (3), the f-number can be reduced as small as $F_1 \times \frac{f}{f_1}$, whereby an astronomical telescope objective lens in which coma aberration and curvature of field can be excellently corrected is achieved. In other words, an optical system is realized which makes it possible for one astronomical telescope to serve as two astronomical telescopes with different f-numbers by using a rear lens group (auxiliary lens) as an adapter for one astronomical telescope.

Next, embodiments of the invention are shown.

Embodiment (1)

An optical system of Embodiment (1) comprises a front lens group including (L_1) and (L_2) and a rear lens group including (L_3) and (L_4), and has the following characteristics.

Focal length: f=824.323mm

Back focal length: Bf=52.928mm

f-number: F=10.3

Focal length of front lens group: f_1=1,200.00mm

Back focal length of front lens group: Bf_1=1,191.790mm

f-number of front lens group: F_1=15

Focal length of rear lens group: f_2=241.372mm

Back focal length of rear lens group: Bf_2=218.735mm

				nd	νd
Front lens group	L_1	R_1=+664.0	d_1=10	1.43387	95.2
		R_2=-357.401	d_2=0.175		
		R_3=-361.182			
	L_2	R_4=-1,269.71	d_3=7	1.5213	52.6
			d_4=1,092.8324		
Rear lens group	L_3	R_5=+121.2	d_5=5	1.63854	55.4
		R_6=-169.7	d_6=7.866		
		R_7=-140.0			
	L_4		d_7=3	1.74	28.3
		R_8= ∞			

Herein,

- R_1 – R_8: radius of curvature of each lens surface (mm)
- d_1 – d_7: lens thickness and air space (mm)
- nd: lens refractive index with respect to the d line
- νd: Abbe's number of lens

Aberrations of the abovementioned embodiment are shown in Fig. 3.

The abovementioned embodiment is a combination of a front lens group and a rear lens group that is an auxiliary lens. Next, aberration comparison with a case where only the front lens group is included and the adapter of the rear lens group is removed is shown.

When only the front lens group is used, the focal length becomes longer than that in the abovementioned embodiment, so

that comparison by setting the same focal length makes aberration comparison clearer, and therefore, data of the lens system obtained by applying the proportion of f/f_1 to the data of the front lens group is shown below. The external appearance view of the lens system is shown in Fig. 4, and aberrations of the same are shown in Fig. 5.

Focal length: $f'=824.323$mm

Back focal length: $Bf'=818.688$mm

f-number: $F'=10.3$

			nd	νd
	$R_1=+456.129$			
L_1		$d_1=6.8694$	1.43387	95.2
	$R_2=-245.513$			
		$d_2=0.1202$		
	$R_3=-248.111$			
L_2		$d_3=4.806$	1.5213	52.6
	$R_4=-872.217$			

Embodiment (2)

An optical system of Embodiment (2) comprises a front lens group including (L1) and (L2) and a rear lens group including (L3) and (L4) (see Fig. 6) and has the following characteristics.

Focal length: $f=439.642$mm

Back focal length: $Bf=52.928$mm

f-number: $F=5.5$

Focal length of front lens group: $f_1=640.00$mm

Back focal length of front lens group: $Bf_1=629.197$mm

f-number of front lens group: F_1=8.0

Rear lens group: same as the rear lens group of Embodiment (1)

				nd	νd
Front lens group	L_1	R_1=+354.133			
			d_1=14.5573	1.43387	95.2
		R_2=-188.546			
			d_2=0.1747		
	L_2	R_3=-190.773			
			d_3=7.2786	1.5213	52.6
		R_4=-672.8086			
			d_4=530.23863		
Rear lens group	L_3	R_5=+121.2			
			d_5=5.0	1.63854	55.4
		R_6=-169.7			
			d_6=7.866		
	L_4	R_7=-140.0			
			d_7=3.0	1.74	28.3
		R_8= ∞			

Aberrations of the abovementioned embodiment are shown in Fig. 7.

The abovementioned embodiment is a combination of a front lens group and a rear lens group that is an auxiliary lens, and next, aberration comparison with a case where only the front lens group is included and the adapter of the rear lens group is removed is shown.

When only the front lens group is included, the focal length

becomes longer than that of the abovementioned embodiment, so that aberration comparison becomes clearer by setting the same focal length, and therefore, data of the lens system obtained by applying the proportion of f/f_1 to the data of the front lens group is shown below. The external appearance view of the lens system is shown in Fig. 8, and aberration diagrams of the same are shown in Fig. 9.

Focal length: $f'=439.642$mm

Back focal length: $Bf'=432.221$mm

f-number: $F'=5.5$

			nd	νd
	$R_1=+243.269$			
L_1		$d_1=10.0$	1.43387	95.2
	$R_2=-129.520$			
		$d_2=0.12$		
	$R_3=-131.050$			
L_2		$d_3=5.0$	1.5213	52.6
	$R_4=-462.180$			

4. BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an explanatory view of the optical system of the invention, Fig. 2 is a side view showing the optical system of the first embodiment, and Figs. 3 show aberrations of the same, wherein (I) shows spherical aberration, (II) shows astigmatism, and (III) shows distortion. Fig. 4 is a side view of only the front lens group whose focal length is set to the same as that of the first embodiment, and Figs. 5 show aberrations

of the same, wherein (I) shows spherical aberration, (II) shows astigmatism, and (III) shows distortion. Fig. 6 is a side view of the optical system of the second embodiment, and Figs. 7 show aberrations of the same, wherein (I) shows spherical aberration, (II) shows astigmatism, and (III) shows distortion. Fig. 8 is a side view of only the front lens group whose focal length is set to the same as that of the second embodiment, and Figs. 9 show aberrations of the same, wherein (I) shows spherical aberration, (II) shows astigmatism, and (III) shows distortion.

In the figures, the symbols (L_1) and (L_2): front lens group, and the symbols (L_3) and (L_4): rear lens group.

Procedure amendment (System)

Date: April 10, 1981

To Mr. Haruki Shimada, Commissioner of Japanese Patent Office:

1. Indication of case:

   Japanese Patent Application No. Sho-55-155182

2. Title of invention: ASTRONOMICAL TELESCOPE OPTICAL SYSTEM

3. Person in charge of amendment

   Relationship with the case: Patent applicant

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   Name: (5569) Tsutomu JINBO (and another)

5. Date of amendment order

   March 5, 1981

6. Object of amendment

   Power of attorney, Section of "BRIEF DESCRIPTION OF THE DRAWINGS" in the specification, and accompanying drawings

7. Details of amendment

(1) Power of attorney: As in the attached sheet.

(2) In the specification, "BRIEF DESCRIPTION OF THE DRAWINGS"

shall be amended as follows.

4. BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an explanatory view of the optical system of the invention, Fig. 2 is a side view showing the optical system of the first embodiment, and Figs. 3 show aberrations of the same, wherein (A) shows spherical aberration, (B) shows astigmatism, and (C) shows distortion. Fig. 4 is a side view of only the front lens group whose focal length is set to the same as that of the first embodiment, and Figs. 5 show aberrations of the same, wherein (A) shows spherical aberration, (B) shows astigmatism, and (C) shows distortion. Fig. 6 is a side view of the optical system of the second embodiment, and Figs. 7 show aberrations of the same, wherein (A) shows spherical aberration, (B) shows astigmatism, and (C) shows distortion. Fig. 8 is a side view of only the front lens group whose focal length is set to the same as that of the second embodiment, and Figs. 9 show aberrations of the same, wherein (A) shows spherical aberration, (B) shows astigmatism, and (C) shows distortion.

In the figures, the symbols (L_1) and (L_2): front lens group, and the symbols (L_3) and (L_4): rear lens group.

(3) "Figs. 3, Figs. 5, Figs. 7, and Figs. 9" of the accompanying drawings are amended as shown on the attached sheets.

Fig.1

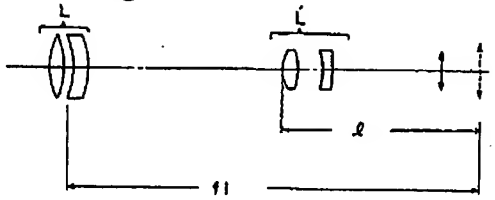

Fig.2

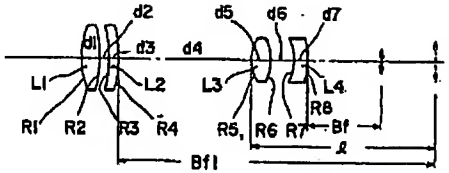

Fig.3

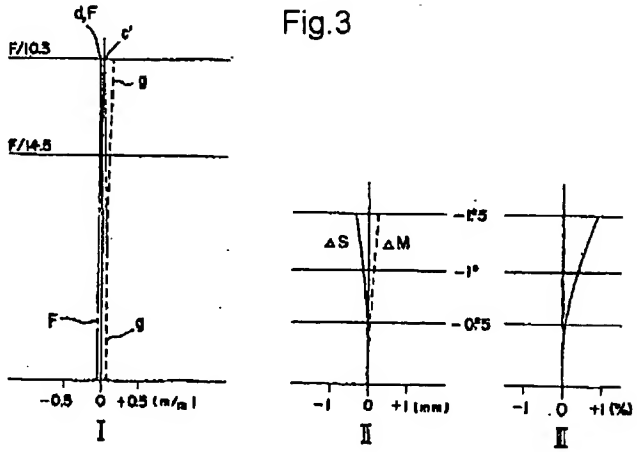

Fig.4

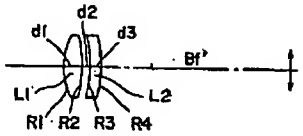

Fig.5

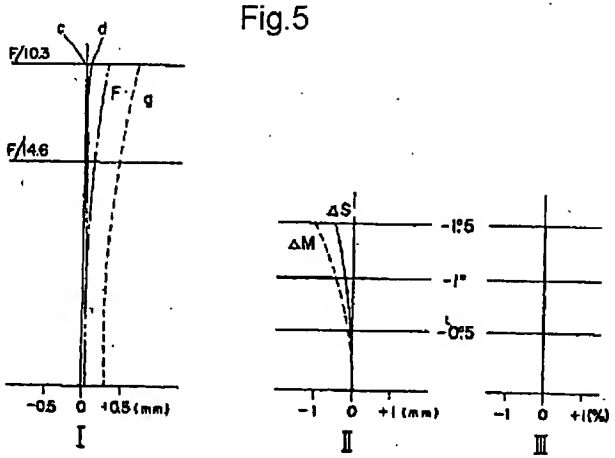

Fig.6

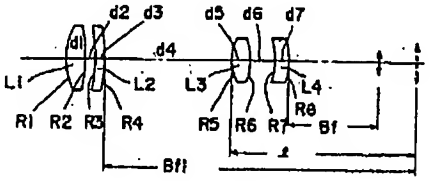

Fig.7

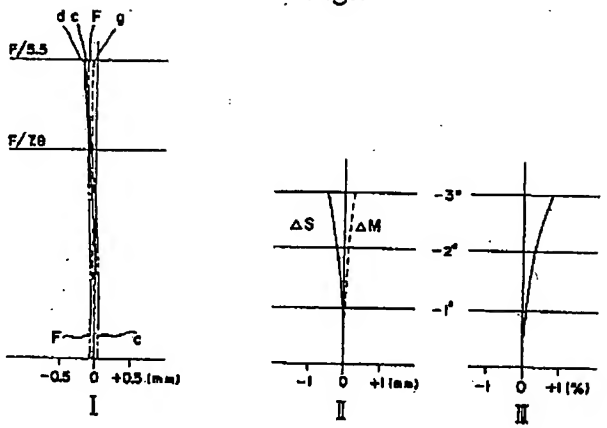

Fig.8

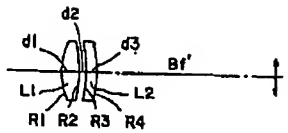

Fig.9

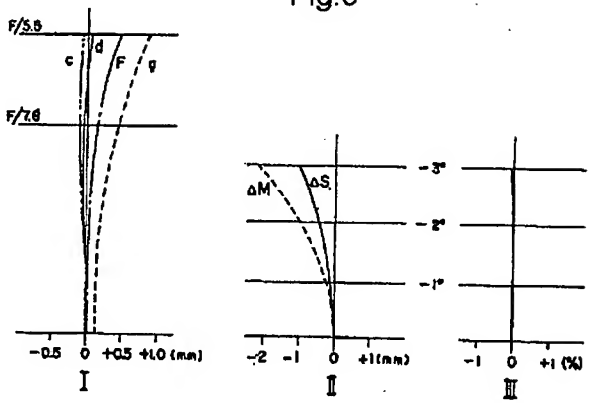

Fig.7

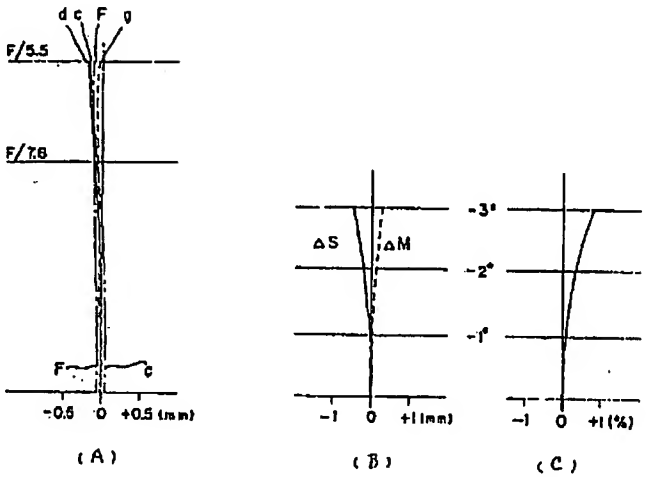

Fig.3

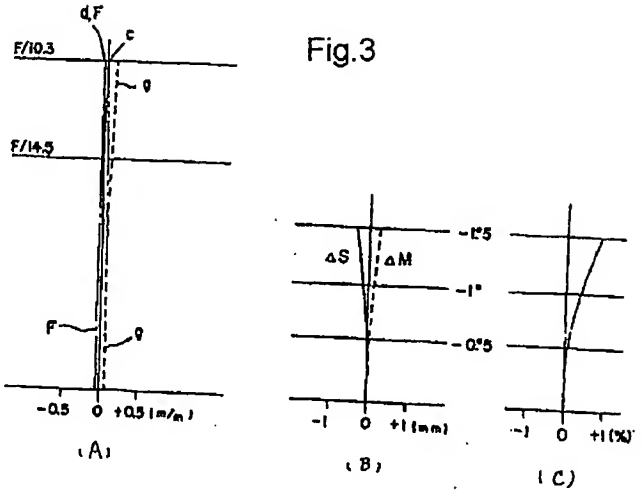

Fig.9

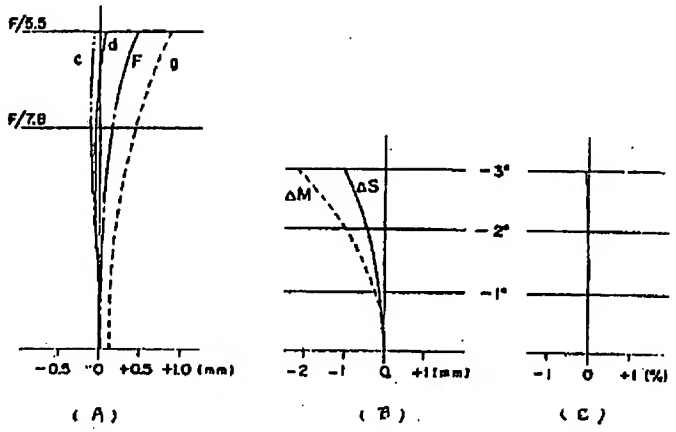

Fig.5